JC08 Rec'd PCT/PTO 3 1 JAN 2001

FORM PTO-1390 (Modified)
(REV 10-95)

U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY'S DOCKET NUMBER
1447

U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR
09/744893

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/DE 00/01878	**JUNE 8, 2000**	**JUNE 22, 1999**

TITLE OF INVENTION
METHOD FOR CALIBRATING THE OFFSET OF ANGLE SENSORS

APPLICANT(S) FOR DO/EO/US
Anton DUKART, Franz JOST

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☐ This is an express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. ☐ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☒ A copy of the International Application as filed (35 U.S.C. 371 (c) (2))
   a. ☐ is transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☒ has been transmitted by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☒ A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. ☐ A copy of the International Search Report (PCT/ISA/210).
8. ☐ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371 (c)(3))
   a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☐ have been transmitted by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☐ have not been made and will not be made.
9. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
10. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371 (c)(4)).
11. ☐ A copy of the International Preliminary Examination Report (PCT/IPEA/409).
12. ☐ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)).

Items 13 to 18 below concern document(s) or information included:

13. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
14. ☒ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
15. ☐ A **FIRST** preliminary amendment.
    A **SECOND** or **SUBSEQUENT** preliminary amendment.
16. ☐ A substitute specification.
17. ☐ A change of power of attorney and/or address letter.
18. ☒ Certificate of Mailing by Express Mail
19. ☐ Other items or information:

EF 215 952 913 US

JC07 Rec'd PCT/PTO 31 JAN 200[illegible]

U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR	INTERNATIONAL APPLICATION NO.	ATTORNEY'S DOCKET NUMBER
09/[illegible]93	PCT/DE 00/01878	1447

20. The following fees are submitted:.

BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)) :

CALCULATIONS PTO USE ONLY

- ☐ Search Report has been prepared by the EPO or JPO **$930.00**
- ☐ International preliminary examination fee paid to USPTO (37 CFR 1.482) **$720.00**
- ☐ No international preliminary examination fee paid to USPTO (37 CFR 1.482) but international search fee paid to USPTO (37 CFR 1.445(a)(2)) **$790.00**
- ☒ Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2) paid to USPTO **$1,070.00**
- ☐ International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(2)-(4) **$98.00**

ENTER APPROPRIATE BASIC FEE AMOUNT =				**$1,000.00**	
Surcharge of **$130.00** for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (e)).				**$0.00**	
CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	2 - 20 =	0	x $18.00	**$0.00**	
Independent claims	1 - 3 =	0	x $80.00	**$0.00**	
Multiple Dependent Claims **(check if applicable).**			☐	**$0.00**	
TOTAL OF ABOVE CALCULATIONS =				**$1,000.00**	
Reduction of 1/2 for filing by small entity, if applicable. Verified Small Entity Statement must also be filed (Note 37 CFR 1.9, 1.27, 1.28) **(check if applicable).**			☐	**$0.00**	
SUBTOTAL =				**$1,000.00**	
Processing fee of **$130.00** for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (f)).			+	**$0.00**	
TOTAL NATIONAL FEE =				**$1,000.00**	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31) **(check if applicable).**			☒	**$40.00**	
TOTAL FEES ENCLOSED =				**$1,040.00**	
				Amount to be: refunded	$
				charged	$

☐ A check in the amount of to cover the above fees is enclosed.

☒ Please charge my Deposit Account No. **19-4675** in the amount of **$1,040.00** to cover the above fees. A duplicate copy of this sheet is enclosed.

☒ The Commissioner is hereby authorized to charge any fees which may be required, or credit any overpayment to Deposit Account No. **19-4675** A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

STRIKER, STRIKER & STENBY
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SIGNATURE

MICHAEL J. STRIKER
NAME

27233
REGISTRATION NUMBER

JANUARY 31, 2001
DATE

4/PRTS

09/744893

JC07 Rec'd PCT/PTO 31 JAN 2001

METHOD FOR CALIBRATING THE OFFSET OF ANGLE SENSORS

The present invention relates to a method for calibrating the offset of angle sensors, which determine an angle to be determined on the basis of a sine signal that can be assigned to the angle and a cosine signal that can be assigned to the angle.

For measuring mechanical angles, measuring methods that are based on the evaluation of sine signals and cosine signals of a sensor are often employed. As examples that can be named in this respect are resolvers in the form of inductive transducers, anisotropic magnetoresistive sensors (AMR sensors), sensors which exploit the giant magnetoresistive effect (GMR sensors), Hall sensors in the form of magnetic angle encoders, and optical or micromechanical transducers.

AMR sensors are used for measuring steering wheel angles, for instance. In such sensors, the angle to be determined is determined via electronic processing of the sine signals and cosine signals of the sensors that can be assigned to the angle to be determined.

The angular precision of such sine-cosine sensors is limited by offset effects. Offset effects can occur especially when the sensors are used at high temperatures. For example, an angle measurement in the motor vehicle engine compartment, where high temperatures typically prevail, leads in the case of conventional angle sensors to offset effects that are not negligible. As a result, the ranges of production variation and operating tolerances for the mechanical,

magnetic, optical or micromechanical components of such sensors must be set as low as possible, which increases their production costs.

The object of the present invention is to disclose a method with which in a simple way the angular precision in angle sensors, especially in angle measurements at high temperatures, can be improved without having to make overly stringent demands in terms of operating tolerance ranges.

This object is attained by a method having the characteristics of claim 1. By means of the method of the invention, the offset of an angle sensor can be calculated and compensated for in a simple way during operation. Compared with conventional versions, this makes it possible to enhance the angular precision, and in particular satisfactory angle measurements can be made at high temperatures, such as in the engine compartment of motor vehicles. The invention makes it possible to increase the ranges of production variation or operating tolerances for the mechanical, magnetic, optical or micromechanical components of the sensors used.

Advantageous features of the method of the invention are the subject of the dependent claims.

In an especially preferred feature of the method of the invention, the determination of the offset Osin of the sine signal is done in accordance with an equation

Osin=1/2*{Ucos(1)-Ucos(3)+[((Usin(2)-Usin(1))*(Usin(2)+Usin(1))/(Ucos(2)-Ucos(1)]-[(Usin(3)-Usin(2))*(Usin(3)+Usin(2)/ (Ucos(3)-Ucos(2)]}/[(Usin(2)-Usin(1))/(Ucos(2)-Ucos(1)-(Usin(3)-Usin(2))/(Ucos(3)-Ucos(2))],

and the determination of the offset Ocos of the cosine signal is done in accordance with an equation

Ocos=1/2*{Usin(1)-Usin(3)+[((Ucos(2)-Ucos(1))*(Ucos(2)+Ucos(1))/(Usin(2)-Usin(1)]-[(Ucos(3)-Ucos(2))*(Ucos(3)+Ucos(2)/(Usin(3)-Usin(2)]}/[(Ucos(2)-Ucos(1))/(Usin(2)-Usin(1))-(Ucos(3)-Ucos(2))/(Usin(3)-Usin(2))],

in which Usin(i), Ucos(i) represent the determined sensor signals for the positions i = 1, 2, 3.

The equations given contain merely elementary operations with regard to three pairs of measurement values, each for different angles. Other types of calculation and in particular trigonometric types of calculation are also possible.

The method according to the invention will now be explained further in conjunction with the accompanying drawing. Shown in this drawing are:

Fig. 1, a graph to schematically illustrate sine signals and cosine signals that can be assigned to an angle;

Fig. 2, a graph to illustrate the offset of an ideal sensor;

Fig. 3, a graph to illustrate the offset of a real sensor; and

Fig. 4, a graph to illustrate the method of the invention, on the basis of three different angular positions of an angle to be determined.

Numerous angle sensors, for certain angular positions that can for instance be represented in the form of angles between the sensor and a rotatable permanent magnet, generate two different signal values, which correspond to the sine and the cosine, respectively, of the angle to be determined. Such sine and cosine signals are schematically shown in Fig. 1. A cosine signal is represented here by the symbol Ucos, and a sine signal is represented by the symbol Usin. It can be seen that at an angle φ of 0°, a signal Usin of 0 and a signal Ucos of 1 are present, which corresponds to an ideal sensor without an offset. The signals of such an ideal sensor for angle measurement are $Usin(\varphi) = A * \sin(\varphi)$, and $Ucos(\varphi) = A * \cos(\varphi)$, in which Usin and Ucos are the sensor signals, A is the amplitude of the signal, and φ represents the mechanical angle. On the basis of two such measurement values, the mechanical angle can be calculated, for instance by means of the relationship $\arctan(Usin(\varphi)/Ucos(\varphi))$.

The ideal state in which no offset in the signals of the angle sensor occurs is shown once again in Fig. 2 in a further graph. Here the signal Usin is plotted on the abscissa, and the signal Ucos is plotted on the ordinate. Since the offset values of both signals are equal to 0, that is, Osin=0 and Ocos=0, all the value pairs Ucos, Usin detected are located on an arc K.

In actual or available angle sensors, however, an offset occurs with regard to both signals, resulting in the following equations:

$$Usin(\varphi) = Osin + A * \sin(\varphi), \text{ and}$$

$$Ucos(\varphi) = Ocos + A * \cos(\varphi).$$

The occurrence of such an offset makes angle measurements actually performed incorrect. This real situation is shown in Fig. 3. It can be seen that the offset values Osin and Ocos are different from 0. The value pairs obtained when such an offset is present are located on an arc K', which however instead of the ideal zero point has the point (Osin, Ocos) as its center point.

The method according to the invention now makes a simple determination of the offset values Osin and Ocos possible, so that on the basis of these determined offset values, a cleaned-up angle calculation can be done.

The problem on which the invention is based resides in the determination of the center point of a circle of which only various points along the arc are known.

Solving this problem will now be explained in further detail in conjunction with Fig. 4. In the example shown there, the center point 0 of the circle is determined on the basis of three points 1, 2, 3 that are located on the arc K'. The coordinates of the various points are as follows:

1: Usin(1), Ucos(1);

2: Usin(2), Ucos(2); and

3: Usin(3), Ucos(3).

In other words, in the present example the determination of the center point O of the circle K' is shown on the basis of the three points 1, 2, 3 of the circle. The coordinates of the center point 0 of the circle correspond to the coordinates of the offset, namely Osin, Ocos.

Since all three points are located on the circle K', the following conditions apply:

[(Ocos-Ucos(1)]*[(Ocos-Ucos(1)]+[(Osin-Usin(1)]*[(Osin-Usin(1)]=[(Ocos-Ucos(2)]*[(Ocos-Ucos(2)]+[(Osin-Usin(2)]*[(Osin-Usin(2)],

and

[(Ocos-Ucos(2)]*[(Ocos-Ucos(2)]+[(Osin-Usin(2)]*[(Osin-Usin(2)]=[(Ocos-Ucos(3)]*[(Ocos-Ucos(3)]+[(Osin-Usin(3)]*[(Osin-Usin(3)].

Solving these equations yields the following values for the coordinates of the center point of the circle K', or in other words the offset values Osin, Ocos:

Usin(1))*(Usin(2)+Usin
(1))/(Ucos(2)-Ucos(1)]-[(Usin(3)-
Usin(2))*(Usin(3)+Usin(2)/ (Ucos(3)-Ucos(2)]}/[(Usin(2)-
Usin(1))/(Ucos(2)-Ucos(1)-(Usin(3)-Usin(2))/(Ucos(3)-
Ucos(2))],

Ocos=1/2*{Usin(1)-Usin(3)+[((Ucos(2)-Ucos(1))*(Ucos(2)+
Ucos(1))/(Usin(2)-Usin(1)]-[(Ucos(3)-Ucos(2))*(Ucos(3)+
Ucos(2)/(Usin(3)-Usin(2)]}/[(Ucos(2)-Ucos(1))/(Usin(2)-
Usin(1))-(Ucos(3)-Ucos(2))/(Usin(3)-Usin(2))].

The formulas for representing the offset values Osin, Ocos contain merely elementary operations of the three pairs of measurement values for the various angles. The offset values Osin, Ocos can therefore be determined in a simple way on the basis of the calculation method indicated.

It will be noted that the temperature should not vary during the detection of the three measurement value pairs 1, 2, 3, since the radius of the circle K' is dependent on the temperature, and hence temperature changes can lead to imprecisions.

Mathematical calculation methods known per se for calculating angles on the basis of sine signals and cosine signals can be expanded according to the invention with the automatic offset calibration shown.

The method illustrated permits an automatic offset calibration upon dynamic rotary motions. No change in the actual sensors is made, either in terms of layout, packaging or manufacture. The change takes place only in an evaluation circuit, and thus conventional sensors can continue to be used, given suitable modification of the evaluation circuit. If the evaluation circuit is

assigned to a microprocessor, only the software has to be changed, by incorporating the indicated calculation method for calculating the offset and compensating for it. It is understood that hardware expansions of the evaluation electronics are also possible. By means of the method of the invention, new possible uses and new possibilities for diagnosis in safety-relevant systems become available. Examples that can be named in this connection are ESP (electronic stability program) and EPS (electronic power steering) with sensors for measuring steering wheel angles, throttle adjustments, and torque.

The method illustrated can advantageously be used in particular in contactless steering wheel angle measurement and torque measurement, regardless of any measurement or sensor principle employed.

Claims

1. A method for calibrating the offset of angle sensors, which determine an angle to be determined on the basis of a sine signal that can be assigned to the angle and a cosine signal that can be assigned to the angle, having the following steps:

- determining the sine signal and the cosine signal for at least three different angles (1, 2, 3) to obtain at least three value pairs (Usin(1), Ucos(1); Usin(2), Ucos(2); Usin(3), Ucos(3)), each containing one sine signal and one cosine signal.

- displaying the at least three value pairs in an at least two-dimensional coordinate system that represents a sine signal-cosine signal plane; and

- determining a point, representing the offset to be calibrated, in the coordinate system with regard to which point the at least three value pairs are located on an arc.

2. The method of claim 1, characterized in that the offset Osin of the sine signal is determined in accordance with an equation

$$\mathrm{Osin}=1/2*\{\mathrm{Ucos}(1)-\mathrm{Ucos}(3)+[((\mathrm{Usin}(2)-\mathrm{Usin}(1))*(\mathrm{Usin}(2)+\mathrm{Usin}(1))/(\mathrm{Ucos}(2)-\mathrm{Ucos}(1)]-[(\mathrm{Usin}(3)-\mathrm{Usin}(2))*(\mathrm{Usin}(3)+\mathrm{Usin}(2)/(\mathrm{Ucos}(3)-\mathrm{Ucos}(2)]\}/[(\mathrm{Usin}(2)-\mathrm{Usin}(1))/(\mathrm{Ucos}(2)-\mathrm{Ucos}(1)-(\mathrm{Usin}(3)-\mathrm{Usin}(2))/(\mathrm{Ucos}(3)-\mathrm{Ucos}(2))]$$

and the offset Ocos of the cosine signal is determined

in accordance with an equation

$$Ocos=1/2*\{Usin(1)-Usin(3)+[((Ucos(2)-Ucos(1))*(Ucos(2)+Ucos(1))/(Usin(2)-Usin(1)]-[(Ucos(3)-Ucos(2))*(Ucos(3)+Ucos(2)/(Usin(3)-Usin(2)]\}/[(Ucos(2)-Ucos(1))/(Usin(2)-Usin(1))-(Ucos(3)-Ucos(2))/(Usin(3)-Usin(2))],$$

wherein Usin(i), Ucos(i) represent the determined sensor signals for the positions i = 1, 2, 3.

Abstract

A method for calibrating the offset of angle sensors, which determine an angle to be determined on the basis of a sine signal that can be assigned to the angle and a cosine signal that can be assigned to the angle, having the following steps:

- determining the sine signal and the cosine signal for at least three different angles to obtain at least three value pairs, each containing one sine signal and one cosine signal;

- displaying the at least three value pairs in an at least two-dimensional coordinate system that represents a sine signal-cosine signal plane; and

- determining a point, representing the offset to be calibrated, in the coordinate system with regard to which point the at least three value pairs are located on an arc.

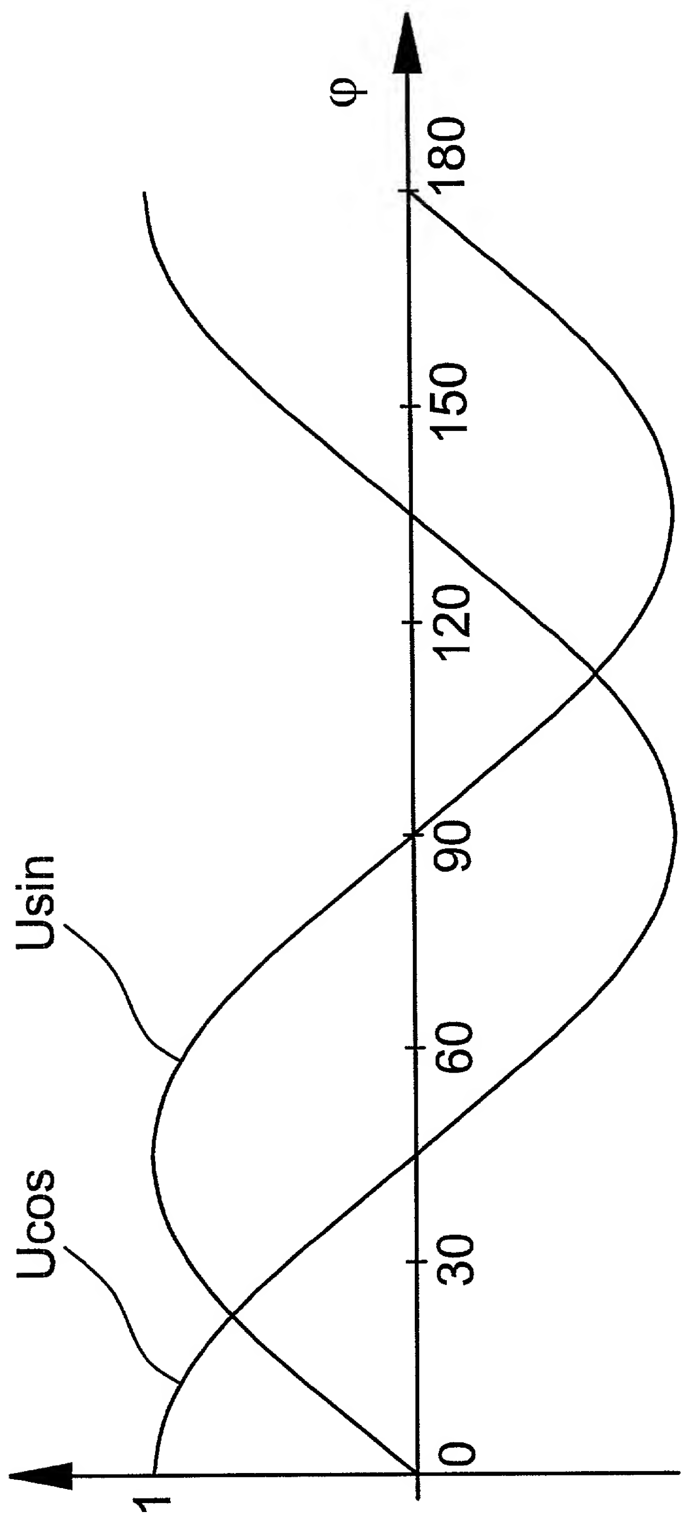
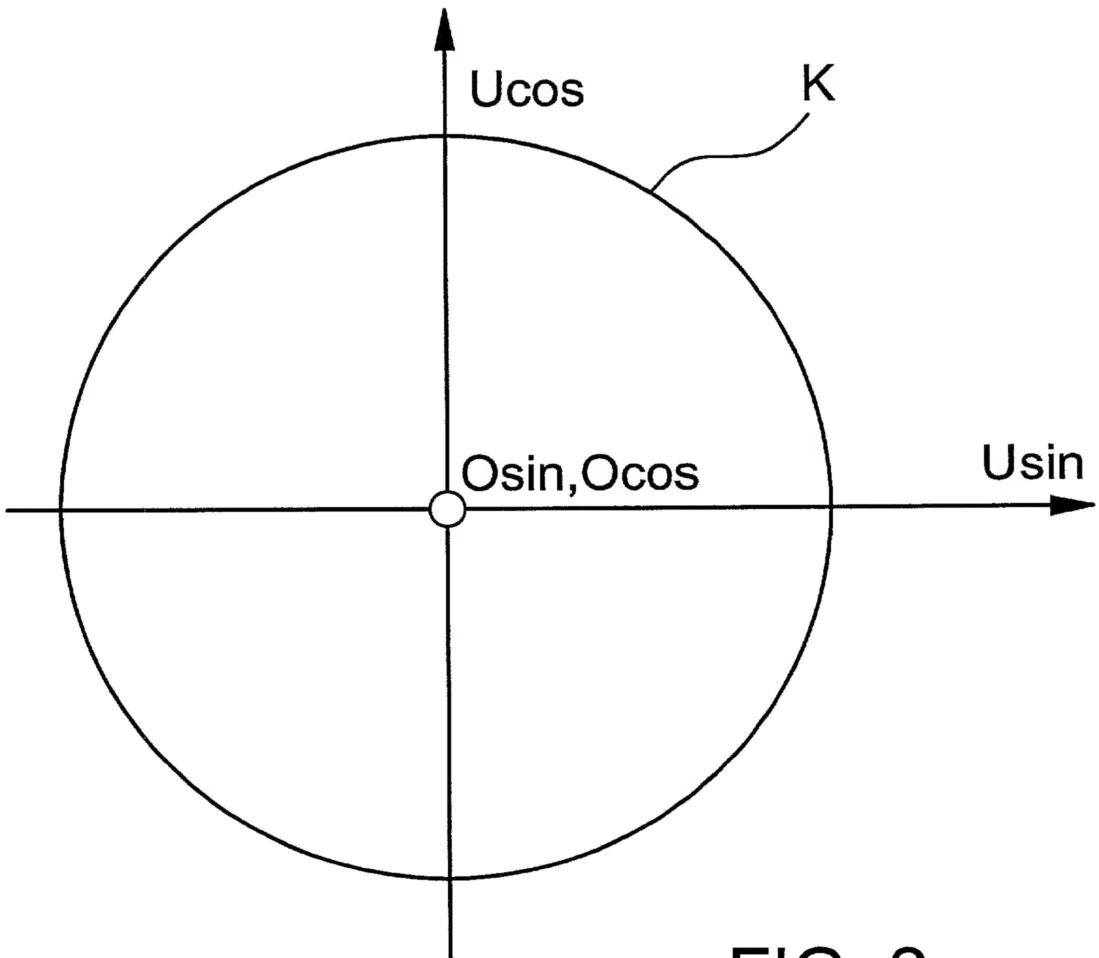


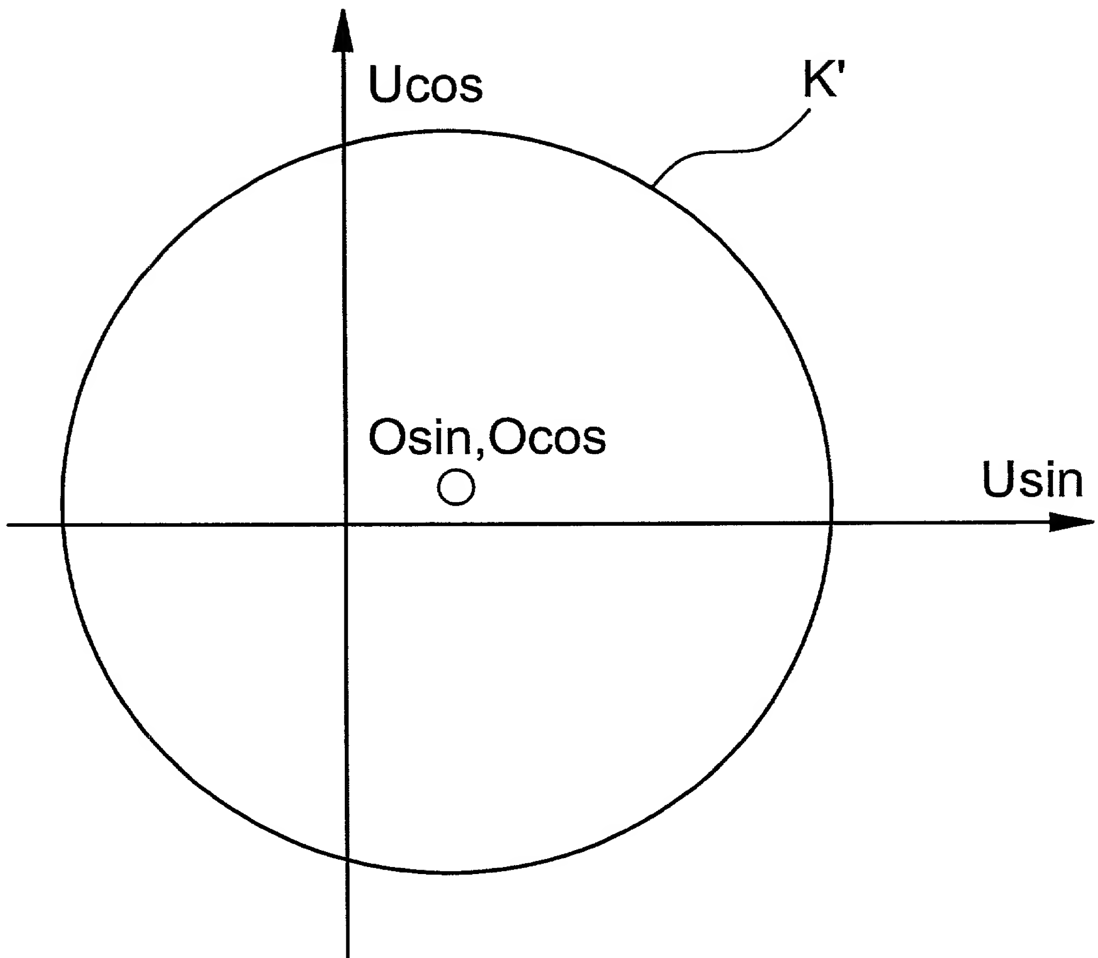
FIG. 1



Osin = 0
Ocos = 0

FIG. 2

09/744893



Osin ≠ 0
Ocos ≠ 0

FIG. 3

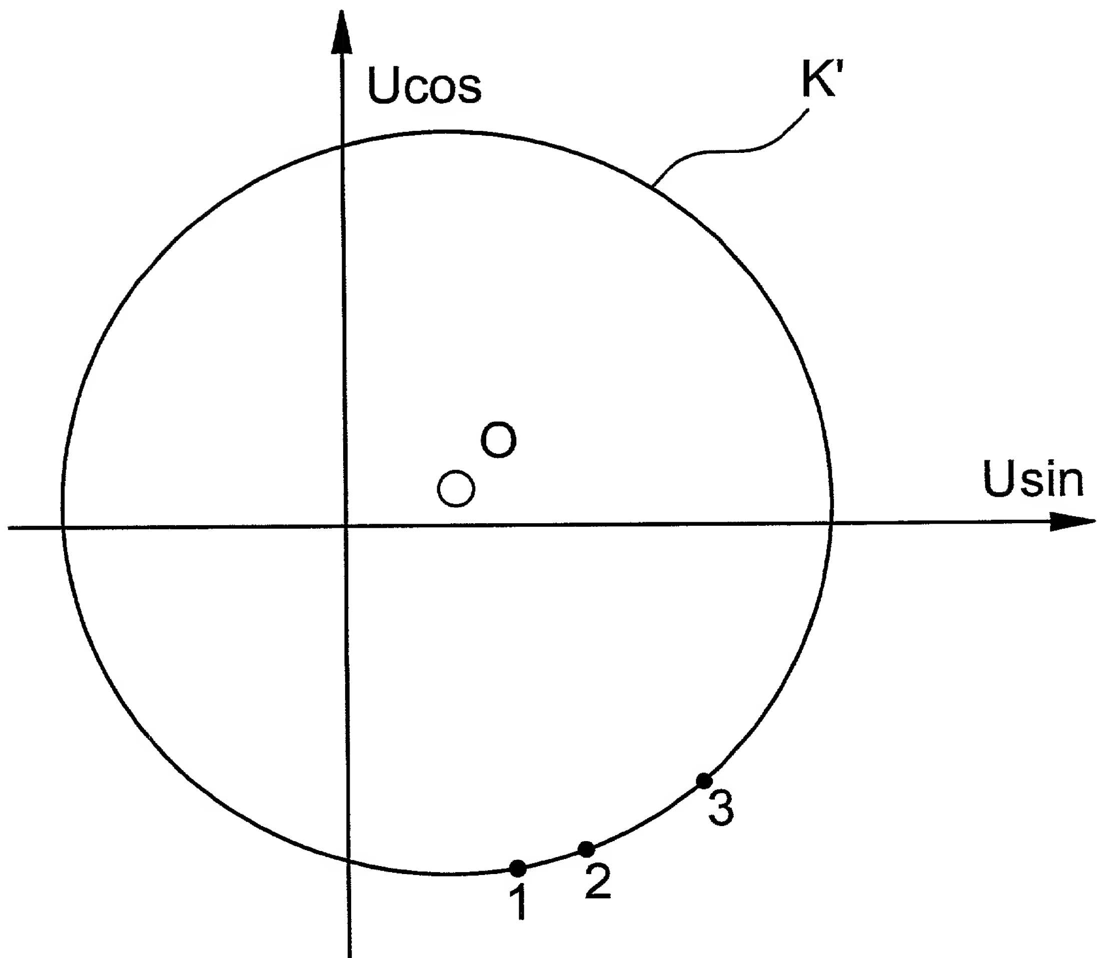


FIG. 4

Wertepaare:
Usin(1), Ucos(1)
Usin(2), Ucos(2)
Usin(3), Ucos(3)

DECLARATION AND POWER OF ATTORNEY FOR NATIONAL STAGE OF PCT PATENT APPLICATION

As a below-named inventor, I hereby declare that:

Anton DUKART
Franz JOST

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled **METHOD FOR CALIBRATING THE OFFSET OF ANGLE SENSORS** the specification of which was filed as PCT International Application number PCT/DE 00/01878 on June 8, 2000.

I hereby state that I believe the named inventor or inventors in this Declaration to be the original and first inventor or inventors of the subject matter which is claimed and for which a patent is sought.

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose all information which is material to the patentability of this application in accordance with Title 37, Code of Federal Regulations, Section 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119(a)-(d) or Section 365 (b) of any foreign application(s) for patent or inventor's certificate, or Section 365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate or PCT International application having a filing date before that of the application on which priority is claimed.

Prior foreign application(s):			Priority claimed:	
199 28 482.2	GERMANY	JUNE 22, 1999	X	
(Number)	(Country)	(Date filed)	Yes	No
(Number)	(Country)	(Date filed)	Yes	No

As a named inventor, I hereby appoint the following attorney to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith:

Michael J. Striker, Reg. No. 27233

Direct all telephone calls to Striker, Striker & Stenby at telephone no.: (631) 549 4700 and address and all correspondence to:

STRIKER, STRIKER & STENBY
103 East Neck Road
Huntington, New York 11743
U.S.A.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that wilful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such wilful false statement

may jeopardize the validity of the application or any patent issued thereon.

Signature: x Anton Dukart	Date: x 11.01.01	Residence and Full Postal Address: Eichenweg 1, 70839 Gerlingen, Germany
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Signature:	Date:	Residence and Full Postal Address:
Full Name of Fourth Inventor:	Citizenship:	
Signature:	Date:	Residence and Full Postal Address:
Full Name of Fifth Inventor:	Citizenship:	
Signature:	Date:	Residence and Full Postal Address:
Full Name of Sixth Inventor:	Citizenship:	
Signature:	Date:	Residence and Full Postal Address:
Full Name of Seventh Inventor:	Citizenship:	
Signature:	Date:	Residence and Full Postal Address:
Full Name of Eighth Inventor:	Citizenship:	
Signature:	Date:	Residence and Full Postal Address:
Full Name of Ninth Inventor:	Citizenship:	